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Title of the Invention

Probe Structure

#### Abstract

Configuration: Bumps 3 are formed in a surface 1b of an insulating layer 1, and leads 2 are formed in a surface 1a of the insulating layer 1. A conductive path 4 for connecting each lead 2 and each bump 3 is formed so as to penetrate the insulating layer in an oblique direction. At the time of conduction inspection, a support 6 is fixed through an adhesive layer 5 in the surface 1a of the insulating layer 1 where the leads 2 are formed.

Positioning of a probe structure P1 and a semiconductor element 10 is carried out so as to bring the bumps 3 into contact with aluminum electrodes 11. Signals of specified frequency for inspecting the conduction of a circuit of the semiconductor element 10 are inputted through the bumps 3 from a tester (not shown) to the electrodes 11 of the semiconductor element 10, thereby inspecting the conduction of the semiconductor element 10.

Effect: When the bumps 3 and the electrodes 11 are brought into contact with each other, the pressure loaded on the electrode 11 is divided and the force applied in the vertical direction (the thickness direction) of the electrodes 11 can be decreased. Accordingly, damage on the bumps 3 and the electrodes 11 can be prevented.

Claim

1. A probe structure, wherein  
contacts brought into contact with terminals of an object to be  
inspected are formed on one surface of an insulating layer,  
circuit wirings connected to a testing device for carrying out a  
conduction inspection for the object to be inspected are formed on the other  
surface of the insulating layer, and  
the contacts and the circuit wirings are connected to each other  
through conductive paths formed on the insulating layer in an oblique  
direction.

#### Detailed Description of the Invention

[0001]

#### Technical Field Pertinent to the Invention

The present invention relates to a probe structure, and more particularly to a probe structure provided at the tip end portion of a testing device such as a tester which is employed for conduction inspection of a semiconductor element, a semiconductor element assembly such as a wafer where semiconductor elements before dicing are formed, and a semiconductor device, and for conduction inspection of a wiring circuit such as a circuit substrate for mounting a semiconductor device thereon, and a circuit substrate for LCD.

[0002]

#### Prior Art

Recently, progress of semiconductor wafer fabrication technology is outstanding. Along with the progress, patterning of IC wiring has been

made fine, and substrates mounting IC with such fine patterns have been increased. In general, such a substrate includes a copper-clad laminate board, a glass substrate, a ceramic substrate and the like and, for conduction inspection of a substrate having fine patterns, a mechanical probe such as a needle type probe has been conventionally employed to carry out point inspection one by one.

[0003]

On the other hand, along with the progress of fineness of the patterns, it becomes difficult to carry out positioning at the time of inspection in the case of using the above-mentioned mechanical probe, and there is a possibility to damage the patterns at the time of positioning. Therefore, a card type probe has been developed to make it possible to collectively carry out the conduction inspection thereby. In addition, in order to moderate the pressure applied at the time of pressing a probe to an electrode pad of a semiconductor element, a probe in which a plurality of bump-shaped metal protrusions are formed has been proposed (see JP Shutsugan Hei 4-179683 and the like).

[0004]

#### Problems to be Solved by the Invention

However, with respect to such a card type probe, it is indispensable to carry out a step of masking with a resin or the like after formation of metal protrusions to be cores in order to form a plurality of semispherical (dome-shaped) metal protrusions in the portions to be brought into contact with patterns of a circuit to be inspected, i.e. head parts. Thus, production of the probe requires a long time and cost. Further, even if metal

protrusions to be brought into contact with electrode pads are formed around the head part, since the pressure loaded at the time when the metal protrusions to be cores are pressed to make contact through conductive paths formed in the thickness direction of an insulating layer is applied to the electrode pads in the vertical direction, the damages on the electrode pads cannot be prevented.

[0005]

Therefore, the present inventors have enthusiastically tried to make improvements in order to provide a probe structure capable of solving the problems of the above-mentioned conventional card type probe, capable of preventing the damages on the electrode pads of an object to be inspected at the time of conduction inspection of the object to be inspected, and capable of preventing the damages of the metal protrusions of the probe themselves, whereby the present invention has completed.

[0006]

#### Means for Solving the Problems

That is, a probe structure according to the present invention is characterized in that contacts brought into contact with terminals of an object to be inspected are formed on one surface of an insulating layer, circuit wirings connected to a testing device for carrying out a conduction inspection for the object to be inspected are formed on the other surface of the insulating layer, and the contacts and the circuit wirings are connected to each other through conductive paths formed on the insulating layer in an oblique direction.

[0007]

The term "an object to be inspected" in the present invention means a semiconductor element, a semiconductor element assembly (a silicon wafer before dicing, a silicon chip after dicing, and the like), a semiconductor device, a circuit substrate for mounting a semiconductor device thereon, a circuit substrate for LCD, and the like. The term "a contact" means a conductor which is made conductive by being connected to a terminal (a pad, a land and the like) of the object to be inspected. The shape of the contact is not particularly limited and may be triangular, regular square, rectangular, trapezoidal, parallelogrammatic, other polygonal, circular, planes, or a solid body such as square pillar, column, spherical, conical, (conical and pyramidal). It is also not necessarily required to be projected outward from the surface of the insulating layer and, depending on the layout of the object to be inspected and the shape of the circuit, it may be designed optionally.

[0008]

Further, the term "a testing device" includes not only a tester but also devices to be employed for impedance conformation between the object to be inspected and the circuit wiring. The term "circuit wiring" include a broad concept including not only wiring patterns but also electrodes and leads. The meaning "to connect" is to carry out electric conduction by physical connection.

[0009]

#### Functions

In a probe structure according to the present invention, since contacts and circuit wirings are connected to each other through conductive

paths formed in an insulating layer in an oblique direction, the pressure loaded on terminals of an object to be inspected is divided and the force loaded on the terminals in the vertical direction (the thickness direction) can be decreased at the time when the contacts and the terminals of the object to be inspected are brought into contact with each other. Accordingly, damages on the contacts and the terminals can be prevented.

[0010]

#### Embodiments

Hereinafter, embodiments will be mentioned in order to describe the present invention in details; however, the present invention is not limited thereto.

[0011]

Fig. 1 is a cross-sectional view showing an embodiment of a probe structure of the present invention. In a probe structure P1 shown in Fig. 1, leads 2 which are circuit wirings are formed on a surface 1a of an insulating layer 1, and the leads 2 are connected to a testing device (a tester) which is not shown. The leads 2 are electrically connected to circuit patterns of an object to be inspected and to electrode terminals on a semiconductor element through bumps 3 and conductive paths 4 which will be described later, and the leads are arranged in desired linear patterns so as to carry out conductive inspection to conform whether a prescribed function is provided or not.

[0012]

Further, in the surface 1b of the insulating layer 1, the bump-like metal protrusions (hereinafter, simply referred to as "bump") 3, which are

contacts, are formed while being protruded outward from the surface 1b of the insulating layer 1 and the bumps 3 are formed at positions to be brought into contact with aluminum electrodes 11 on a semiconductor element 10, which is an object to be inspected.

[0013]

In regions where the leads 2 are brought into contact with the insulating layer 1 or their peripheral regions including the regions, conductive paths 4 penetrating the insulating layer 1 in the oblique direction are formed, and the conductive paths 4 are connected to leads 2 and bumps 3.

[0014]

Herein, it is no need to say that the present invention includes an embodiment, as shown in Fig. 1, in which contacts do not rise like bumps and the conductive paths 4 are formed up to the plane same as the surface 1b of the insulating layer 1 and the end parts become the contacts.

[0015]

In the case of inspection, a supporting body 6 is fixed, for example, in the surface 1a of the insulating layer 1, where the leads 2 are formed, through an adhesive layer 5, and positioning of the probe structure P1 and the semiconductor element 10 is carried out. The probe structure P1 and/or the semiconductor element 10 are shifted in the direction in which both come closer to bring the bumps 3 and the aluminum electrodes 11. Signals of specified frequency for conduction inspection of circuits of the semiconductor element 10 are inputted to the electrode terminals of the semiconductor element 10 from a tester through the bumps 3 to carry out

the conduction inspection of the semiconductor element 10. On completion of the conductive inspection, the probe structure P1 and/or the semiconductor element 30 are shifted in the direction in which both are parted from each other and the above-mentioned operation is repeated to carry out conduction inspection of a new semiconductor element.

[0016]

Since the leads 2 and the bumps 3 are connected through the conductive paths 4 formed in the oblique direction in the insulating layer 1, when the bumps 3 and the aluminum electrodes 11 are brought into contact with each other, the pressure to be loaded on the aluminum electrodes 11 of the semiconductor element 10 is divided and the force to be loaded in the vertical direction of the aluminum electrodes 11 can be decreased.

Accordingly, damages on the bumps 3 and the aluminum electrodes 11 can be prevented.

[0017]

A material for forming the insulating layer 1 and the supporting body 6 is not particularly limited if it is a film having an electric insulation property. Specifically, examples thereof may include a thermosetting resin or a thermoplastic resin such as a polyester-based resin, an epoxy-based resin, an urethane-based resin, a polystyrene-based resin, a polyethylene-based resin, a polyamide-based resin, a polyimide-based resin, an acrylonitrile-butadiene-styrene (ABS) copolymer resin, a polycarbonate-based resin, a silicone-based resin, a fluoro-based resin, and among them, from a viewpoint that it is excellent in heat resistance and mechanical strength and also has a linear expansion coefficient in good

balanced with that of an object to be inspected, a polyimide-based resin is particularly preferable to be used.

[0018]

The thickness of the insulating layer 1 is not particularly limited; however, in order to provide a sufficient mechanical strength and proper flexibility, it is preferably adjusted to be 2 to 500  $\mu\text{m}$ , more preferably 10 to 150  $\mu\text{m}$ . Further, the thickness of the supporting body 6 is preferably adjusted to be 5 to 200  $\mu\text{m}$ , more preferably 25 to 100  $\mu\text{m}$  in order to provide a sufficient mechanical strength and proper flexibility.

[0019]

A material for constituting the adhesive layer 5 includes an epoxy-based resin, an alkaline-based resin and the like, and the thickness of the adhesive layer 5 is preferably adjusted to be 5 to 200  $\mu\text{m}$ , more preferably 20 to 100  $\mu\text{m}$ .

[0020]

A material for constituting the leads 2, which are circuit wirings, the bumps 3, and the conductive paths 4 is not particularly limited if it has conductivity and well known metal materials can be used, and examples thereof include a single metal such as gold, silver, copper, platinum, lead, tin, nickel, cobalt, indium, rhodium, chromium, tungsten, ruthenium and the like and various alloys containing these components, for example, a solder, a nickel-tin alloy, a gold-cobalt alloy, and the like. Herein, it is preferable to use a metal, for example a noble metal such as rhodium, ruthenium, platinum and the like, with a high hardness, difficult to be oxidized, and having a low electric resistance so as to make it easy to break an oxide layer

on the aluminum electrodes 11, which are terminals of an object to be inspected, and an insulating layer on wiring patterns.

[0021]

The thickness of the leads 2, which are circuit wirings, is not particularly limited; however, it is preferably set to be 1 to 200  $\mu\text{m}$ , more preferably 5 to 80  $\mu\text{m}$ .

[0022]

The height of the bumps 3 from the surface 1b of the insulating layer 1 is not particularly limited, it is preferably set to be 0.1  $\mu\text{m}$  to several hundreds  $\mu\text{m}$ . The bumps 3 are formed in a mushroom-shape (an umbrella-shape) as shown in Fig. 1 and a semispherical shape as well. Also, the shape of the bumps 3 may be a triangular, a rectangular, or circular shape and in the case the bottom face shape is made to be circular, the entire shape to be formed may be a semispherical or column shape and depending on the layout of the object to be inspected, they may be designed optionally.

[0023]

A material for constituting the conductive paths 4 may be the same material as that for constituting the bumps 3 or a different substance, however generally the same substance is used and in such a case, the bumps 3 and the conductive paths 4 are preferably formed integrally in terms of production.

[0024]

Further, Fig. 2 is a cross-sectional view showing another embodiment of a probe structure of the present invention. As shown in a

probe structure P2 in Fig. 2, the probe structure may be a structure using three types of forming materials. That is, an economical metal substance such as copper or the like is used for the conductive paths 4 connected to leads 2 and gold or the like with a high connection reliability is used for the surface layer 3a of the bumps 3 to be brought into contact with the aluminum electrodes 11. Further, a nickel or the like as a barrier metallic substance to prevent mutual reaction of metallic substances is used for an interlayer 3b existing between the conductive paths 4 and the surface layer 3a. The structure is not limited to the above-mentioned structure using three types of forming materials and may be a structure using four or more types of forming materials.

[0025]

Fig. 3 is a cross-sectional view showing still another embodiment of a probe structure of the present invention. As shown in a probe structure P3 in Fig. 3, the probe structure may have a plurality of minute metal protrusions 31 in the surface of each bump 3. The metal protrusions 31 may be formed using a single metal or alloy other than that of the bumps 3. Generally, as a forming material for the bumps 3, economical nickel or copper with a high conductivity is preferable to be employed, whereas as a forming material for the metal protrusions 31, a noble metal such as rhodium, ruthenium, platinum and the like, with a high hardness, difficult to be oxidized, and having a low electric resistance is preferable to be used so as to make it easy to break an oxide layer on the aluminum electrodes 11 and an insulating layer on wiring patterns.

[0026]

Since if mutual reaction occurs between the bumps 3 and the metal protrusions 31, they respectively change the metal physical properties, and in order to keep the metal physical properties, a barrier metal is preferable to be laid between the bumps 3 and the metal protrusions 31. For example, in the case diffusion takes place just like the case of the combination of gold and copper, nickel as a barrier metal is preferable to be laid between gold and copper. In the case where the bumps 3 and the metal protrusions 31 are formed by plating using a single metal, plating conditions under which metals become brittle due to hydrogen embrittlement and sulfur embrittlement are not preferable. For example, nickel metal formed by using a nickel sulfamate plating solution or adding a sulfur-containing additive such as saccharin, sodium naphthalenesulfonate and the like as a brightening agent for the nickel plating solution forms an eutectic crystal of pure nickel and intermetallic compound,  $\text{Ni}_3\text{S}_2$ , and in the case where heating in post-treatment, the  $\text{Ni}_3\text{S}_2$  intermetallic compound forms agglomerate to result in brittleness.

[0027]

By forming the minute metal protrusions 31 on the surface of the respective bumps 3 as described above, for example, an oxide layer on the aluminum electrodes 11 and an insulating layer on wiring patterns are easy to be broken and a plurality of contact points are formed between the aluminum electrodes 11 and the bumps 3 to make it possible to carry out reliable conduction inspection.

[0028]

Fig. 4 is a cross-sectional view of yet another embodiment of a probe

structure of the present invention and as shown in a probe structure P4 in Fig. 4, a protection resin layer 7 may be formed on the surface 1b of the insulating layer 1 where the bumps 3 are formed. The protection resin layer 7 is formed with a thickness of generally 5 to 50  $\mu\text{m}$ , preferably 10 to 30  $\mu\text{m}$  and, as the protection resin, a thermosetting resin such as an epoxy-based resin or a thermoplastic resin such as a fluoro-based resin is used.

[0029]

In Fig. 4, the protection resin layer 7 is previously formed on the surface of the insulating layer 1 and then the bumps 3 are formed; however, it may be formed by thermally press-bonding a film-shaped or ribbon-shaped protection resin layer 7 after bumps 3 are formed or by extrusion molding or spread coating the protection resin. In such a case, the bumps 3 and the metal protrusions 31 are required not to be completely covered with the protection resin layer 7.

[0030]

By forming such a structure, damages on an object to be inspected by a head part can be prevented at the time of performing conduction inspection. Further, in the case where the protection resin layer 7 is provided after formation of the bumps 3, the bumps 3 and metal protrusions 31 are protected and prevented from dropping.

[0031]

Fig. 5 shows a cross-sectional view showing the production process of the probe structure of the present invention and, for example, the production may be carried out as follows.

[0032]

At first, as shown in Fig. 5(a), a lamination substrate comprising an insulating layer 1 and a conductive substance layer 8 laminated on the surface 1a of the insulating layer 1a by a known method is prepared. Examples of a formation method of the conductive substance layer 8 on the surface of the insulating layer 1 include a sputtering method, a variety of evaporation methods, a variety of plating methods and the like. Further, a method using a conductor foil for the conductive substance layer 8 or laminating the insulating layer 1 on a conductor foil or a method by applying an insulator to a conductor foil and then solidifying the insulator can be exemplified as a method for forming the conductive substance layer 8 on the insulating layer 1.

[0033]

Next, as shown in Fig. 5(b), after a resist layer is formed on the surface 8a of the conductive substance layer 8 for electric insulation, by employing photolithographic process, the resist in the region other than the regions where leads 2 are to be formed is removed by chemical etching treatment. After that, the conductive substance layer 8 is etched to be formed in desired linear patterns.

[0034]

Next, as shown in Fig. 5(c), through holes 9 penetrating the insulating layer 1 up to the lead 2 are formed in an oblique direction. Formation of the through holes 9 is important to form electric connection between the leads 2 and the bumps 3 and in a region of the insulating layer 1 where the leads 2 are brought into contact with the insulating layer 1 or

the periphery of the region, at least one minute through hole 9 is formed with a narrower inter-hole pitch than the width of the lead 2. The inclination of the through holes 9 is 30° or more and less than 90°, preferably 45° to 80°. If the inclination of the through holes 9 is less than 30°, the cushioning property probably becomes insufficient to result in incapability of preventing damages on bumps 3 and the aluminum electrodes 11.

[0035]

Formation of the through holes 9 with an optional hole diameter and inter-hole pitches may be carried out by a mechanical piecing method such as punching, plasma processing, laser processing, photolithographic processing chemical etching using a resist with different chemical resistance from that of the insulating layer 1, laser processing capable of carrying out ultra fine processing to response to the tendency of fine pitch requirement. Above all, piecing processing by radiating excimer laser with controlled pulse frequency and energy quantity is preferable. The hole diameter of the through holes 9 is 5 to 200  $\mu\text{m}$ , preferably 8 to 50  $\mu\text{m}$ . It is preferable in terms of decrease of the electric resistance of the conductive paths 4 to be formed in the through holes 9 that the hole diameter of the through holes 9 is made as wide as possible to the extent that neighboring through holes are not made continuous and the inter-hole pitches are also made as narrow as possible to increase the number of the through holes 9.

[0036]

Next, as shown in Fig. 5(d), a protection insulating layer 12 is formed on the surface 1a of the insulating layer 1. After that, the through

holes 9 are filled with a conductive substance to form the conductive paths 4 and the bumps 3 and then the protection insulating layer 12 is removed by a common method to obtain a probe structure P1 as shown in Fig. 5(e).

[0037]

Formation of the conductive paths 4 and the bumps 3 can be performed by a method for physically filling the through holes 9 with a conductive substance, a CVD method, a plating method such as electroplating, electroless plating, and the like, a chemical method for precipitating a conductive substance by immersing a structure obtained by the above-mentioned processes in a molten bath of the conductive substance and the pulling out the structure; however, a method by electroplating using leads 2 as electrodes is a simple method and therefore preferable. In the present invention, filling a conductive substance not only means physically burying the conductive substance but also burying by the above-mentioned chemical precipitation and means a broad concept including through hole plating for carrying out tube-shaped plating on the wall faces of the through holes 9.

[0038]

In order to form the metal protrusions 31 as shown in Fig. 3, for example, the following methods can be employed.

[0039]

At first, after the bumps 3 are formed and before the metal protrusions 31 are formed, a metal powder is dispersed in a plating bath and electroplating is carried out. By such a manner, a metal powder is deposited on the surface of the bumps 3 and forms a seed (a core) at the time

of plating growth to form the metal protrusions 31. The metal powder to be dispersed is preferably an ultra fine powder in order to form the minute metal protrusions 31 and those with a particle diameter of 0.01 to 200  $\mu\text{m}$ , preferably 0.1 to 50  $\mu\text{m}$ , further preferably 1 to 3  $\mu\text{m}$ , may be used.

[0040]

Further, as shown in Fig. 3, it is preferable to form the metal protrusions 31 in the vicinity of the top of each bump 3 from a viewpoint that the contacts can be increase at the time of conductive inspection. In order to carry out formation in such a manner, the above-mentioned electroplating is preferably carried out while a magnetic field being generated in the top direction of the bumps 3, that is, the hole formation direction of the through holes 9. The intensity of the magnetic field in such a case is about 1 KT to 15 KT, preferably about 2 KT to 5 KT. Herein, in the case of carrying out electroplating under magnetic field application, a magnetic metal such as nickel, cobalt and the like is used as the metal powder to be dispersed in the plating solution.

[0041]

Further, as another method, there is a method for forming a seed for formation of metal protrusions 31 on the surface of the bumps 3 by spraying a plating solution in which a metal powder is dispersed to the surface of the bumps 3 by employing a circulation pump.

[0042]

Further, as still another method, there is a method for carrying out electroplating by applying ultrasonic wave to a plating bath. In such a case, the surface of the bumps 3 is preferable to be activated by etching treatment

or the like in terms of formability of the metal protrusions 31.

[0043]

Hereinafter, a more specific production example of a probe structure of the present invention will be described. A polyimide precursor solution was applied to a 35  $\mu\text{m}$ -thick copper foil to form a film with a thickness of 25  $\mu\text{m}$ , dried and cured to form a bilayer film comprising the copper foil and the polyimide film.

[0044]

Next, after a resist layer was formed on the surface of the copper foil to insulate the copper foil, employing photolithographic process, desired linear patterns were formed.

[0045]

Next, KrF excimer laser beam with oscillated wavelength of 248 nm was radiated to the polyimide film surface through a mask from the direction at  $45^\circ$  to the thickness direction of the polyimide film to form minute through holes in the polyimide film with a diameter of 60  $\mu\text{m}\phi$ , pitches of 200  $\mu\text{m}$ , and a depth of 25  $\mu\text{m}$  in a number of 5 per 1  $\text{mm}^2$  in a region of 8  $\text{cm}^2$ .

[0046]

Next, a resist was applied to the copper foil surface and cured to insulate the copper foil surface and then the copper foil was immersed in a chemical polishing solution at  $50^\circ\text{C}$  for 2 minutes. After the resulting foil was washed with water, the copper foil part is connected to an electrode and immersed in a gold cyanide plating bath at  $60^\circ\text{C}$  and using the copper foil as a negative pole, gold plating was grown in the through hole parts of the

bilayer film and when the gold crystal was protruded out the surface of the polyimide film (the height of the protrusion was about 5  $\mu\text{m}$ ), the plating treatment was interrupted. Finally, the applied resist layer was removed to obtain a probe structure of the present invention.

[0047]

#### Effects of the Invention

As described above, with respect to a probe structure of the present invention, since contacts and circuit wirings are connected through conductive paths formed in an oblique direction of an insulating layer, when the contacts and terminals of an object to be inspected are brought into contact with each other, the pressure loaded to the terminals of the object to be inspected is divided and the force loaded in the vertical direction (the thickness direction) of the terminals can be decreased. Accordingly, damages on the contacts and the terminals can be prevented. Further, at the time of forming contact, the probe structure itself has a cushioning effect and sufficiently moderates the stress even if the stress is applied externally and the contacts together with the conductive paths do not probably drop out the insulating layer.

#### Brief Description of the Drawings

Fig. 1 is a cross-sectional view showing an embodiment of a probe structure of the present invention.

Fig. 2 is a cross-sectional view showing another embodiment of a probe structure of the present invention.

Fig. 3 is a cross-sectional view showing still another embodiment of a probe structure of the present invention.

Fig. 4 is a cross-sectional view showing yet another embodiment of a probe structure of the present invention.

Figs. 5(a) to 5(e) are cross-sectional views showing production processes of a probe structure of the present invention.

#### Explanation of Symbols

1: insulating layer

1a: the other surface

1b: one surface

2: lead (circuit wiring)

3: bump (contact point)

4: conductive path

10: semiconductor element (object to be inspected)

11: aluminum electrode (terminal)

P1: probe structure